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Quantitative Evaluation of Air Filtration Systems in Use at Asbestos Abatement Sites: Research in Progress

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16. ABSTRACT

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QUANTITATIVE EVALUATION OF AIR FILTRATION SYSTEMS IN USE AT ASBESTOS ABATEMENT SITES: RESEARCH IN PROGRESS

by

John R. Kominsky
Ronald W. Freyberg
James M. Boiano
PEI Associates, Inc.
11499 Chester Road
Cincinnati, OH 46268

Thomas J. Powers
William C. Cain
Roger C. Wilmoth
U. S. Environmental Protection Agency
Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268

James A. Brownlee
James H. Lucas, Jr.
Donald R. Gerber
Asbestos Control Service
New Jersey Department of Health
Trenton, NJ 08625

Paper Presented at the
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Anaheim, California

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ABSTRACT

High Efficiency Particulate Air (HEPA) filtration systems serve as the principal engineering control to remove asbestos particulate from airstreams at abatement projects. However, little quantitative information is available on the integrity of these air filtration systems in preventing asbestos fiber release into outdoor air or adjacent building areas, potentially exposing occupants. A study is in progress to assess the performance of HEPA filtration systems in use at asbestos abatement projects to determine each systems operating particle-removal efficiency, percent penetration, and decontamination factor. The asbestos fiber concentration in the inlet and discharge air of each filtration system will be determined by isokinetic air sampling. Each isokinetic air sample collected will be analyzed using transmission electron microscopy. In addition, in-place aerosol performance testing will be conducted according to procedures outlined in ANSI/ASME N510-1980. The test method utilizes a polydispersed dioctyl phthalate aerosol (generated by Laskin nozzles) and a photometric light-scattering mass-concentration detector as the measuring device.

INTRODUCTION

Abatement work practices and procedures recommended by the U.S. Environmental Protection Agency (EPA) in "Guidance for Controlling Asbestos-Containing Materials in Buildings" (EPA 560/5-85-024) include the use of negative-air pressure systems with high efficiency particulate air filters as an integral part of the abatement containment system. Although these systems are the principal engineering control for removal of asbestos particulate from airstreams in active abatement areas, very little quantitative information is available on their integrity in actual use in preventing asbestos fiber release from these areas. Laboratory and field studies[1,2] on a small number of air filtration systems suggest the lack of preventive maintenance, operator misuse, or poor equipment design may result in operating performance less than stated in the manufacturer's specifications. Therefore, systems operating at substandard performance could be releasing asbestos fibers into the outdoor air or adjacent building areas where building occupants could be exposed.

A study is in progress to assess the performance of HEPA-filtration systems in use at asbestos abatement projects to

determine each system's operating particle-removal efficiency, percent penetration, and decontamination factor. The field effort for this study is currently in progress; therefore, this paper presents only the study design and progress to date.

EXPERIMENTAL DESIGN

This study will be conducted during the removal phase of asbestos-abatement projects. Thirty air filtration units will be selected for testing from those in service at abatement sites in New Jersey. Access to abatement sites in New Jersey will be coordinated by the Asbestos Control Service of the State of New Jersey Department of Health. Because selection of the air filtration units will be based on availability, the units may not be representative of those used at all asbestos-abatement sites; therefore, the study results cannot be generalized to apply to all units.

Test procedures for each of the 30 air filtration units to be evaluated during this study include 1) determination of asbestos fiber concentration in the inlet and discharge air; 2) determination of asbestos fiber concentration in ambient air outside the abatement site; and 3) in-place aerosol performance testing.

Asbestos Air Sampling

Isokinetic Sampling--

Isokinetic sampling of the inlet and discharge air of the filtration system will be conducted to determine the respective asbestos fiber concentrations. In isokinetic sampling, the velocity of air entering the sample nozzle (V_n) is the same as the velocity of the airstream (V_s). That is, the sample nozzle tip opening area (A_n) and the sample volume flow rate (V_n) must be adjusted to obtain a velocity ($V_s = V_n/A_n$) equal to the airstream velocity (V_s) at the sampling point. The sampling constraint, ($V_n = V_s$), is termed isokinetic sampling or equal-velocity sampling.

Isokinetic sampling rates are needed for particulate sampling in ducts when the airstream velocities exceed 1000 feet per minute (ft/min) to ensure that the sample collected is representative of the stream being sampled.[3] The extent to which the sample will not be representative depends primarily on the amount of departure from the isokinetic velocity and the size of the particles.[4] For example, a velocity error of 25 percent (2500 ft/min duct velocity and 2000 ft/min sampling velocity) for a 5-um particle would result in an isokinetic sampling error of 3 percent, whereas the same velocity error (25%) for a 17-um particle would be approximately 9 percent.[4] Although the size characteristics of the particles to be sampled are not known,

available data suggest that the particles in the discharge air will be predominately less than 5 micrometers in length.[5] Therefore, minimal deviations from isokinetic sampling conditions are not expected to result in significant sampling errors. Nevertheless, because HEPA-filtered systems typically have air duct velocities in excess of 1000 ft/min and the size characteristics of the particles to be sampled are not known, sampling will be conducted as close to isokinetic conditions as possible.

Figure 1 shows a sketch of the isokinetic sampling nozzle/filter assembly. The isokinetic sampling train consists of a brass metal nozzle; a three-piece non-conductive filter cassette containing a 25-mm, 0.45-um pore-size mixed cellulose ester filter mounted on a 5-um pore-size mixed cellulose ester backup diffusing filter and cellulose support pad; a flow-control device; and a vacuum pump. The nozzle will be mounted directly to the filter cassette to minimize sample loss. Duplicate sampling trains will be used during each test run, i.e., duplicate samples will be collected in both the inlet and discharge air ducts. The sampling assemblies will be positioned in the duct so that each nozzle is 1/3 duct diameter from the duct walls (Figure 2). The spatial variability of asbestos concentration across the cross section of the duct will be minimized by locating the sampling points eight duct diameters from the last bend or point of flow disturbance.[6]

The sampling flow rate will be based on duct velocity at the point where the sampler nozzle will be positioned. The samples will be collected for a period long enough to achieve a minimum air volume of 2200 liters. The duct volumetric flow rate will be determined by 20 measurements taken at multiple points in an equal area traverse of the duct.[7]

Ambient Air Sampling--

Ambient air samples will be collected on 25-mm diameter, 0.45-um pore-size, mixed cellulose ester membrane filters. Each 25-mm filter will be mounted on a 5-um pore-size mixed cellulose ester backup diffusing filter and cellulose support pad. The filter assembly will be contained in a three-piece cassette with a face cap. A minimum air sampling volume of 2200 liters (flow rate of approximately 10 liters/min) will be achieved for all samples. Four ambient air samples will be collected outside the building and distant from the air filtration system discharge.

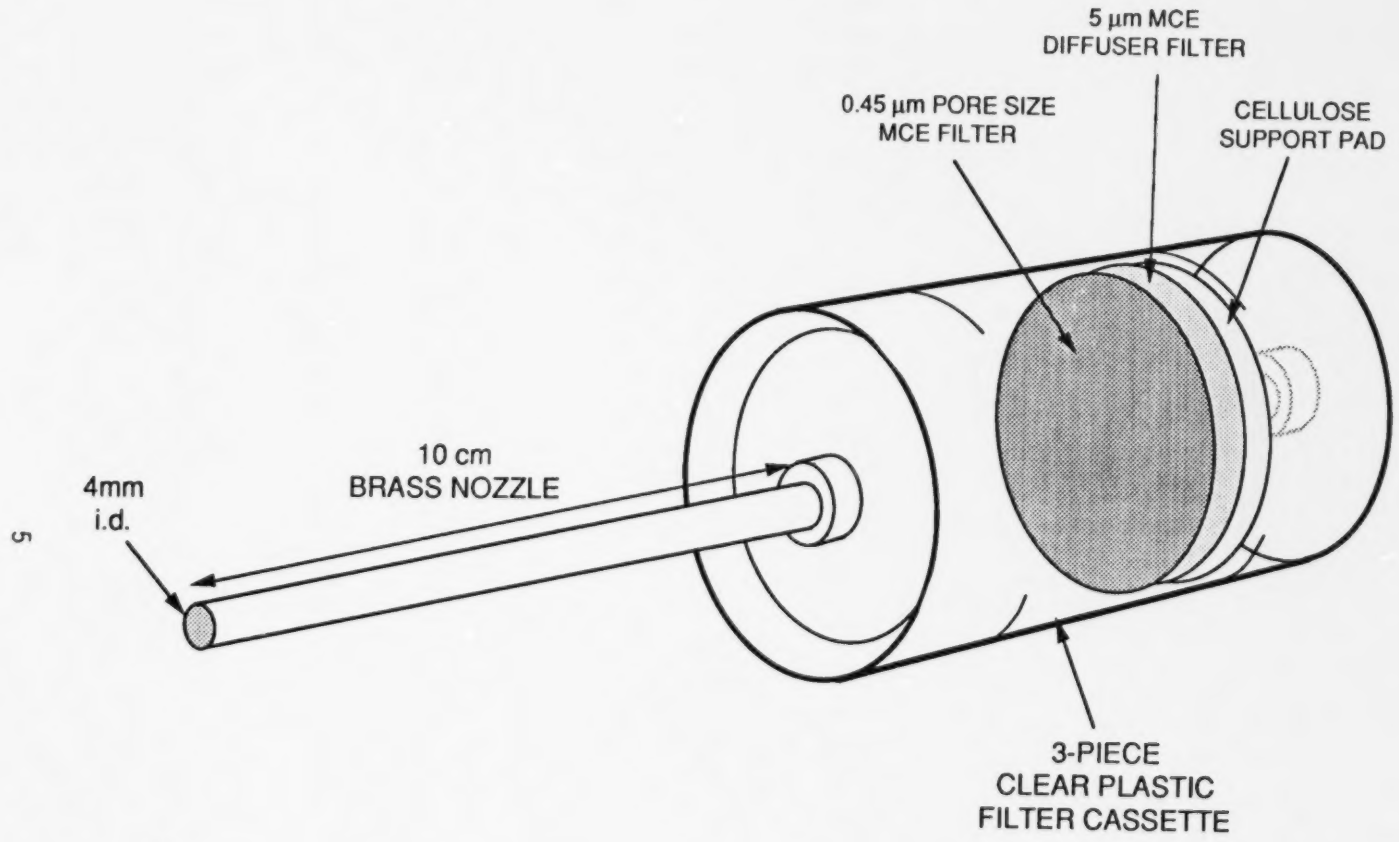

Figure 1. Filter cassette/nozzle assembly.

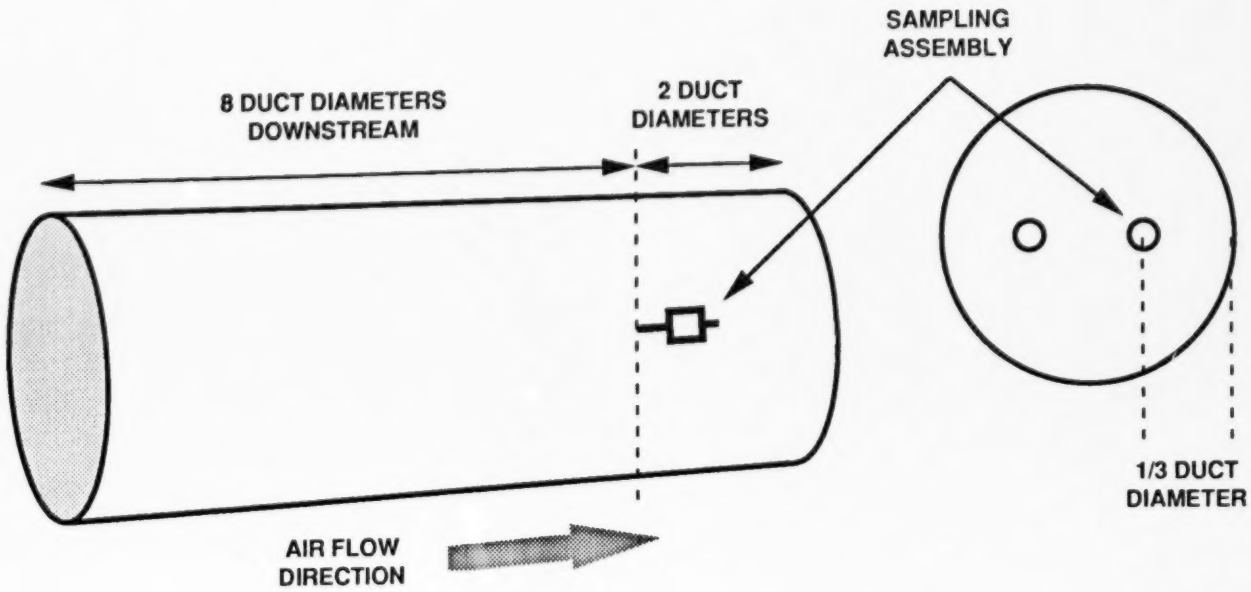

Figure 2. Location of isokinetic sampling nozzle discharge air duct

In-Place Aerosol Performance Test

The in-place aerosol performance test will be conducted in accordance with the standard procedures outlined in ANSI/ASME N510-1980 to determine the particle-removal efficiency, percent penetration (the percentage of particles passing through the HEPA filtration system), and decontamination factor for each HEPA system.[8] An in-place aerosol performance test is designed to challenge all parts of the filtration system. This test is used in the nuclear industry during acceptance testing of an air filtration system, after any filter replacement or after any maintenance activity in the filter housing to verify 1) that the filters have not been damaged, 2) that the filters have been installed properly, and 3) that there are no leaks in the mounting frame or between the mounting frame and the housing. Figure 3 illustrates the test setup for the HEPA filtered air system.

The ANSI/ASME N510-1980 method involves the use of a polydispersed dioctyl phthalate (DOP) aerosol (generated by means of Laskin nozzles) and a photometric light scattering mass-concentration detector as the measuring device. The DOP is a polydispersed liquid aerosol having an approximate light-scattering mean droplet-size distribution as follows:

99% less than 3.0 Microns
95% less than 1.5 Microns
92% less than 1.0 Microns
50% less than 0.7 Microns
25% less than 0.45 Microns
11% less than 0.3 Microns

With the system operating, air-generated DOP aerosol is injected upstream of the system. Concentration measurements are then made upstream and downstream of the system. The particle-removal efficiency, percent penetration, and decontamination factor are calculated as follows:

Percent Penetration, $P = (C_d/C_u) \times 100$

Percent Efficiency, $E = (100 - P)$

Decontamination Factor, $DF = (1/P)$

where

C_d = downstream concentration

C_u = upstream concentration

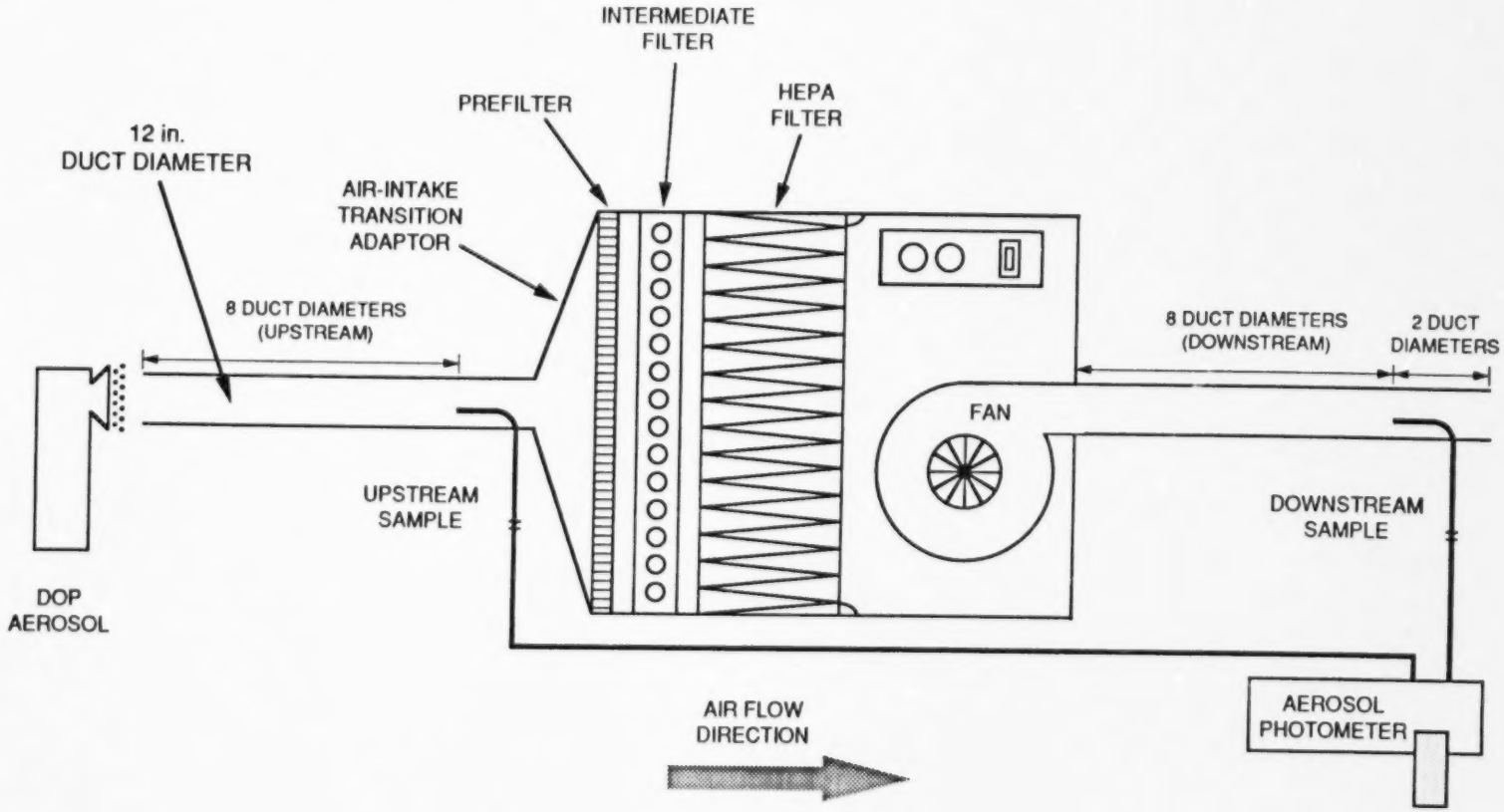

Figure 3. HEPA-filtered air system test setup.

ANALYTICAL METHODS

Asbestos Fibers

All isokinetic and ambient air samples will be analyzed in accordance with the nonmandatory Transmission Electron Microscopy (TEM) method as described in the Asbestos Hazard Emergency Response Act (AHERA) final rule (52 CFR 41821) with two exceptions: 1) AHERA stopping rules for fiber counting will be ignored, and 2) an indirect method of filter preparation will be used, because of the need to rinse down the isokinetic sampling cassette/nozzle assembly.

The indirect method of filter preparation involves the ashing of the mixed cellulose ester filter, ultrasonic re-dispersal of the ash in water, and refiltration on to a new mixed cellulose ester filter which will then be prepared by the direct method of filter preparation.

As part of the indirect method of filter preparation, the attached isokinetic sampling nozzle from each isokinetic air sample will be flushed to dislodge any fibers that may have adhered to the inside of the nozzle. Additionally, the sample cassette and face cap will also be washed and refiltered as part of the indirect preparation to account for any asbestos that may have adhered to the walls of the cassette assembly.

Similarly, as part of the indirect method of sample preparation for the ambient air samples, the filter cassette and face cap will be washed and refiltered.

DOP Aerosol

The DOP aerosol will be measured real-time using a Sinclair Phoenix Aerosol Photometer Model JM-8000. The photometer operates on the forward light scattering method of particulate detection, i.e., sensing of scattered light on the side of the particulate opposite the light source. The amount of light scattered is related to the mass concentration of the particles present in terms of micrograms per cubic meter of air sampled.

QUALITY ASSURANCE

Asbestos Sampling

Specific quality assurance procedures will be used to ensure the accuracy and precision of the collection and analysis of the air samples, including filter lot blanks, field blanks, sealed blanks, duplicate counting and replicate analysis.

Filter lot blanks are filters selected at random from the lot of filters to be used for the study to determine the background asbestos contamination level.

Field blanks are filters taken into the field and handled in a similar manner as the exposed air samples to inspect for contamination that might not be a result of air sampling. Two field blanks will be collected at each site. One field blank will be collected inside the building near the entrance to the abatement area and one field blank will be collected outdoors at each site.

Sealed blanks are filter cassettes not opened in the field. These samples will be sealed and submitted to the analytical laboratory to ensure that there is no blank interference during the analytical procedures. One sealed blank will be collected at each site.

As a means of measuring analytical variability introduced by the filter preparation procedure, five percent of the samples collected will be selected for replicate analysis. Replicate analysis refers to the analysis of two grid preparations from the same sample.

As a means of measuring intralaboratory precision, five percent of the samples collected will be selected for duplicate analysis. Duplicate analysis refers to the analysis of the same grid preparation by a second microscopist.

In-Place Aerosol Performance Test

The DOP aerosol generator and photometer will be calibrated and operated in accordance with ANSI/ASME N510-1980.[8]

PROGRESS TO DATE

Evaluation of Isokinetic Air Sampler

The filter cassette/nozzle assembly (Figure 1) was evaluated in a wind tunnel to determine if the design would create significant aerodynamic interference during sampling. Significant aerodynamic interference created by the filter cassette assembly in the duct might bias the concentration of asbestos fibers collected on the filter.

The wind tunnel used in this study (Figure 4) consisted of a Dayton two-speed fan connected to a 4-inch i.d. duct. The filter cassette assembly was positioned in the center of the wind tunnel duct, 10 duct diameters downstream (40 inches) and two duct diameters upstream (eight inches) from the duct exit. Air velocity in the wind tunnel during this study was approximately 2600 feet per minute.

Before the filter cassette assembly was inserted into the

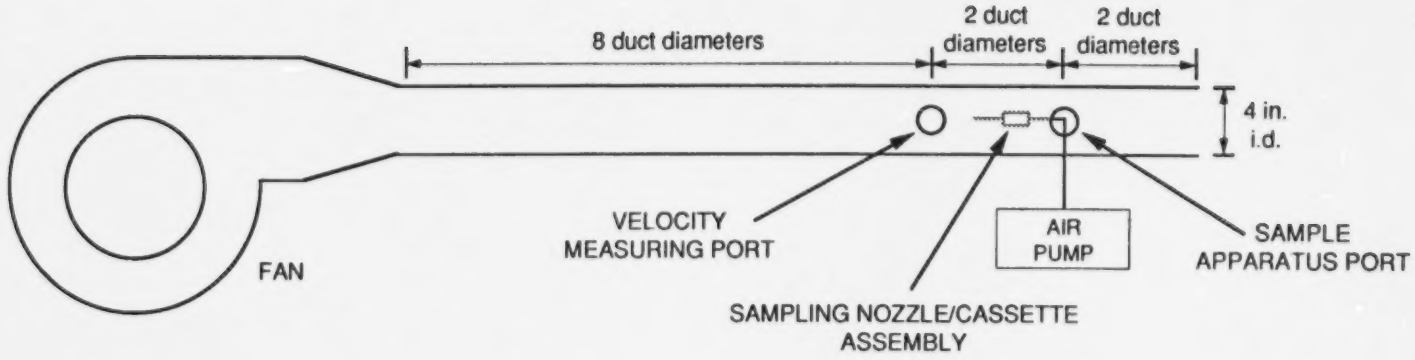

Figure 4. Wind tunnel setup.

wind tunnel duct, a five-point velocity profile of the unobstructed duct was conducted. A pitot tube and an inclined gauge oil manometer were used to measure the velocity pressures in the wind tunnel. The filter cassette was then positioned in the duct, and the velocity profiles were conducted two duct diameters (eight inches) upstream of the nozzle tip and in a plane at the face of the opening of the nozzle tip.

Table 1 summarizes the velocity profile data. These data indicate that the presence of the filter cassette assembly did not alter the laminar flow pattern or significantly affect the velocity profile of the wind tunnel duct.

TABLE 1. VELOCITY PROFILE DATA FROM WIND TUNNEL STUDY

Point	Distance into duct, in.	Velocity, ft/min
Velocity Profile - Clear Duct		
1	1/2	2698
2	1	2738
3	2	2619
4	3	2619
5	3 1/2	2619
Velocity Profile - 8 in. from sampling probe		
1	1/2	2698
2	1	2698
3	2	2619
4	3	2619
5	3 1/2	2619
Velocity Profile - At nozzle inlet		
1	1/2	2627
2	1	2694
3	2	2660
4	3	2560
5	3 1/2	2525

Pilot Study of Test Setup

A laboratory pilot study was conducted on a single HEPA filtration unit prior to the field effort to evaluate the designed system test setup. Isokinetic sampling in the inlet and discharge air ducts was simulated. An in-place aerosol performance was also conducted. No problems with the sampling or test system design were identified.

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